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ABSTRACT

The Corrective Feedback Paradigm (CFP), which has been refined and expanded through use on the PLATO IV Computer-Based Education System, is based on instructional design strategies implied by stimulus-locus analyses, direct instruction, and instructional feedback methods. Features of the paradigm include adaptive feedback techniques with discrimination training and increasing ratio review. Within the context of this computer-based instructional drill paradigm, a study using the PLATO IV system examined the effects of several types of corrective feedback and review procedures on students' posttest achievement and time to mastery. Subjects were 102 college seniors enrolled in an educational psychology course, who were randomly assigned to one of 6 drill treatment groups. The task involved learning 20 English-Japanese (transliterated) word pairs. Planned orthogonal comparisons demonstrated the statistical superiority on posttest performance of increasing ratio review and adaptive feedback with discrimination training, with no significant differences in time to mastery. The most important instructional implication of CFP is that it allows the use of a drill format to teach generalizable concepts. This report lists 20 references.
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An Adaptive Feedback and Review Paradigm for Computer-Based Drills

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Abstract

Since the early uses of computers in education, drill and practice programs have ranked as one of the most widely employed and effective of computer-based instructional techniques. Yet, in spite of the pervasiveness of these drills, relatively little attention has been devoted to discovering ways of maximizing their efficiency and effectiveness, thereby decreasing instructional time and increasing retention. A direct instruction approach is proposed in this paper with the Corrective Feedback Paradigm (CFP). Features of the paradigm include adaptive feedback techniques with discrimination training, and increasing ratio review. One hundred and two undergraduate students were randomly assigned to one of six drill treatment groups. The task consisted of learning 20 English-Japanese (transliterated) word pairs. Planned orthogonal comparisons demonstrated the statistical superiority on posttest performance of increasing ratio review and adaptive feedback with discrimination training, with no significant differences in time to mastery. Using the CFP to teach generalizations is presented.

An Adaptive Feedback and Review Paradigm for Computer-Based Drills

Since the early uses of computers in education, drill and practice programs have been a widely employed (Kearsley, 1976) and effective (Viscnhaler & Bass, 1972) computer-based instructional technique. Most computer drills are modeled after the traditional flash card drill. To increase their effectiveness, Atkinson (1972a, 1972b) applied the techniques of optimal control theory and a mathematical learning model (Atkinson & Crothers, 1964; Calfee & Atkinson, 1965; Groen & Atkinson, 1966) to optimize item sequencing in paired-associate drills.

While Atkinson's work demonstrates that mathematical optimization of items produces improved drill procedures, his simple model has several limitations, and if used by itself, the model could lead to a number of instructionally disadvantageous consequences. For example, it allows the same item to be presented several times in a row (massed practice), although research indicates that spacing of presentations is a more effective technique (Peterson, Wampler, Kirkpatrick, & Saltzman, 1963; Greeno, 1964; Young, 1971; Hintzman, 1974). In Atkinson's study (1972b), as well as in an earlier study (Dear, Silberman, Estavan, & Atkinson, 1967), massed practice was avoided by imposing spacing on top of the optimal procedure, but it is not a characteristic of the model itself. Moreover, the model ignores any inter-item relationships (Atkinson, 1972b), and, as noted by Atkinson and Paulson (1972), and earlier by Gilpin (1962), maximization of performance subject to a fixed number of trials may be a less appropriate formulation of the problem than minimization of study time subject to a fixed minimum performance level.

We took a different approach to the problem of constructing more effective and efficient computer-based drills. The "Corrective Feedback Paradigm" (CFP) is based on instructional design strategies implied by stimulus-locus analyses and direct instruction (Engelmann & Carnine, 1982) as well as instructional feedback methods (Kulhavy, 1977). This drill paradigm has been refined and expanded over several years of use on the PLATO Computer-based Education System (Smith & Sherwood, 1976), although it would work on any hardware or software configuration, including micro-computers.

The Corrective Feedback Paradigm

To the traditional flashcard drill, the corrective feedback paradigm adds several features only available in a computerized drill environment. Each is discussed briefly below.

Adaptive Feedback

The type of corrective feedback provided by the CFP is a function of the type of mistake made. If the student types a response which is not an answer to another item in the drill list--an out-of-list error (OLE)--the correct answer is provided. In a drill on the periodic table of the elements, for example, if the student types "metal" for the stimulus "Cu," and if "metal" is not an answer to another drill item (i.e., is not a name for one of the 103 chemical elements in the periodic table), the paradigm provides the correct answer: "Cu is copper."

If the student types a response which is an answer to another item in the drill list--a discrimination error (DE)--discrimination feedback is provided. For example, if the student types "cobalt" (the answer for the stimulus "Co") instead of "copper" (the answer for the stimulus "Cu"), DE feedback is provided: "cobalt is Co; Cu is copper." Discrimination feedback tells what stimulus the student responded to as well as the answer to the stimulus that was actually presented.

Discrimination Training

In addition to a different form of feedback for DE's, CFP gives students discrimination training. Both the item missed and the item with which it was confused are presented simultaneously, so that the student can study their similarities and differences. For example, if a student answers "copper" for the stimulus "Co," both "Co" and "Cu" are presented together, and the student must respond correctly to both stimuli before returning to the drill.

Discrimination training is completed when both items (presented in random order) are answered correctly. Of course, if a mistake is made during discrimination training, OLE or DE feedback is provided. During discrimination training, however, new DEs (e.g., confusing "Co" for "carbon") are treated as OLEs because it would be confusing for the student to receive discrimination training on more than one DE at a time.

Increasing Ratio Review

Traditional computerized drills emulate the procedures used in non-computerized drills; namely, an incorrectly answered item is placed at the end of the stack of items to be presented, and a correctly answered item is removed from the stack. However, there are two problems with this procedure for reviewing a missed item: (a) if there

are many items left in the stack, the correct response for the missed item probably will be forgotten by the time the missed item reappears for review; and (b) if there are few items left in the stack, the student will not have been "shaped" into remembering the correct response over a longer time period. The CFP addresses both of these problems by using an increasing ratio review schedule.

After the student makes a mistake and receives either OLE or DE corrective feedback (and possibly discrimination training), the missed item reappears according to a spaced review schedule determined by the designer, who may specify up to three review positions (RP). For example, if RP1 is 3, RP2 is 6, and RP3 is 10, then the first review of the missed item would occur three item presentations after the error was made; if that review were answered correctly, the second review would be given six item presentations after the first review; and if that review were answered correctly, the third review would be given ten item presentations after the second review. At any stage during this review schedule, an incorrect response on a reviewed item would reinitiate the review sequence (beginning with RP1) for that item.

This "rearranging of the queue" is analogous to placing an incorrectly answered flash card not at the bottom of the stack but in the middle, according to the increasing ratio review parameters specified. In practice, however, it would be unbearably difficult to implement increasing ratio review with flash cards because the student can make a mistake on more than one item and the review schedules therefore would interact. Fortunately, computers can easily handle this type of bookkeeping task!

Retirement Criterion

If an item is correctly answered, it is placed at the end of the stack or queue of items in the drill. Then the next item in the queue is presented to the student. An item is retired (dropped) from the queue of items when it has been answered correctly k consecutive times, where k is specified by the designer of the drill. For example, if k is 2, each item must be answered correctly two times without an intervening mistake on that item.

All of these features of the CFP--adaptive feedback, discrimination training, increasing ratio review, and retirement criterion--are adjustable for each individual application. The paradigm is used on the PLATO computer-based system, for example, to present drills on medical terminology, spelling, arithmetic facts, English and foreign language vocabulary, U.S. Constitution, reading comprehension skills, English as a second language, identification of bones, and others. Each implementation uses specially designed screen displays which give little outward indication that they are variations on the same theme. Parameters like the retirement criterion and the review schedules for items that are missed are set for each application. The form of discrimination feedback and training are also selected according to the needs of the particular application.

Study

The purpose of the study was to examine, within the context of a computer-based instruction drill program, the effects of several types of corrective feedback and review procedures on the student's posttest achievement and time to mastery.

Method

The task consisted of learning 20 English - Japanese (trans-literated) word pairs--an unfamiliar task to the subjects. The words were selected so as to maximize semantic, phonologic, and orthographic similarities (eg: "like - suki"; "dislike - kirai"; nice - kirei"; "hateful - nikui"; beef - niku").

Design. There were six treatment groups, each varying the type of review and corrective feedback: Group 1 (increasing ratio review and adaptive feedback with training); Group 2 (immediate review only and adaptive feedback with training); Group 3 (increasing ratio review and adaptive feedback); Group 4 (immediate review only and adaptive feedback); Group 5 (no review and adaptive feedback); and Group 6 (increasing ratio review and fixed feedback).

For Groups 1 - 5, the type of corrective feedback following an error was contingent on the type of error ("adaptive"). If the student made an out-of-list error, the answer was provided. For example, if the student typed "omama" for "mother" and "omama" was not a response to another stimulus in the list, out-of-list error feedback was "mother is okaasan." If the student made a discrimination (or intralist) error, discrimination feedback was provided. For example, if the student typed "obasan" for "mother," discrimination error feedback was "obasan is aunt; mother is okaasan."

For Group 6, corrective feedback was the same ("fixed") for out-of-list errors and discrimination errors. In each case the correct answer was provided (eg: "mother is okaasan").

For Groups 1 and 2, discrimination training always followed discrimination error feedback. That is, if two English words were confused they were displayed simultaneously (in random order) and the student was required to type the Japanese equivalent for each stimulus. For Groups 3 - 6 discrimination training never followed the corrective feedback of discrimination errors.

For Groups 1, 3, and 6, missed items were reviewed on an increasing ratio schedule (1-, 3-, 5-later review). For Groups 2 and 4, missed items were reviewed immediately (1-later review). For Group 5, no review was provided; after receiving corrective feedback the student proceeded to the next item.

For all groups, each item was "retired" from the queue when it was answered correctly on two consecutive presentations of that item.

The treatment groups were chosen to address three major research questions (questions 1, 2, and 3 below) and two minor questions (4 and 5). Each question was posed with regard to its effect on the number of posttest DEs and OLEs as well as to its effect on instructional time:

1. Is there any effect for increasing ratio review (Groups 1 and 3), as opposed to immediate review only (Groups 2 and 4)?
2. Is there any effect for adaptive feedback with training (Groups 1 and 2), as opposed to adaptive feedback alone (Groups 3 and 4)?
3. Is the effect of review the same whether or not it is accompanied by a particular type of feedback (Groups 1 and 4 versus Groups 2 and 3)?
4. Is the effect of immediate review only (Group 4) the same as no review (Group 5)?
5. Is the effect of adaptive feedback (Group 3) the same as fixed feedback (Group 6)?

Questions 1, 2, and 3 form a set of comparisons corresponding to tests of main effect for review, main effect for feedback, and interaction of review and feedback, respectively. Questions 4 and 5 amount to control group comparisons.

Subjects. The subjects were 102 college seniors enrolled in an educational psychology course. Participation in the experiment fulfilled a course requirement. Seventeen students were randomly assigned to each of the six experimental groups. None of the students had prior coursework in Japanese nor familiarity with the language.

Procedure. The entire experiment was controlled by the University of Illinois PLATO IV computer-based educational system (Smith & Sherwood, 1976). Under every condition the student first received a short on-line orientation to the keyboard and general instructions on interacting with PLATO. Then every student was administered a typing ability test. Thirty unfamiliar foreign language (non-Japanese) vocabulary words were individually displayed and the student copied (typed) the word and pressed the "NEXT" key. The student then was presented with a randomly ordered list of the 20 English-Japanese word pairs. The list was displayed for two minutes and the student was instructed to learn as many word pairs as possible during the allotted time. Following the display, each English word was presented individually and the student was instructed to type the Japanese equivalent or press the NEXT key if unable to provide an answer. After this pretest, the student was informed that an instructional drill session was to begin which would enable the student to master the Japanese words.

The instructional drill involved a series of self-paced discrete presentations. Each presentation began by displaying an English word on the screen. The student was required to type the Japanese (trans-literated) equivalent or press the "ANS" key if unable to provide a translation. If the student correctly translated the English word, the drill indicated "ok" adjacent to the student's response; the next item in the queue then was presented. If the student asked for the answer or incorrectly responded, corrective feedback, discrimination training, and/or review procedures were initiated according to the student's treatment group. All students were instructed to study each feedback message. When all of the items were retired the drill session ended. The student then answered some attitude questions, took an on-line English vocabulary test (48 items), and then took a posttest on the English-Japanese pairs approximately 20 minutes after the instruction concluded. Unlike the pretest, an answer was required for each item on the posttest.

Results

Table 1 shows the observed group means, standard deviations, and ranges for three dependent measures: (a) number of DEs on the posttest; (b) number of OLEs on the posttest; and (c) time to criterion (instructional time).

For purposes of the analyses, the DE and OLE scores were transformed using the reciprocal transformation $X' = 1/(X+1)$, since the square of treatment means and standard deviations were found to be proportional.

Questions 1 - 3 were analyzed as a set of planned orthogonal comparisons:

1. Main effects for review: Groups receiving increasing ratio review made significantly fewer DEs on the posttest than did the groups receiving immediate review only, $F(1,96) = 12.93$, $p < .001$. Similarly, the increasing ratio review groups made significantly fewer OLEs on the posttest than did the immediate review only groups, $F(1,96) = 31.58$, $p < .001$. There were no significant differences among these groups for instructional time, $p > .05$.
2. Main effects for feedback: Groups receiving adaptive feedback with training made significantly fewer DEs on the posttest than did the groups receiving adaptive feedback only, $F(1,96) = 4.96$, $p < .05$. However, there were no significant differences among these groups for the number of OLEs on the posttest or for instructional time, $p > .05$.
3. Interaction of review and feedback: There were no interaction effects for the number of DEs or OLEs on the posttest or for instructional time, $p > .05$.

Table 1

Group Means, Standard Deviations, and Ranges for
Discrimination Errors, Out-of-List Errors, and Instructional Time

Group	Features	DEs	OLES	Instructional Time (minutes)
1	Adaptive Feedback with Discrimination Training; Increasing Ratio Review	M: 0.24 SD: 0.44 Range: 0 - 1	1.06 1.20 0 - 4	35.02 17.74 18.02 - 83.08
2	Adaptive Feedback with Discrimination Training; Immediate Review Only	M: 2.41 SD: 2.55 Range: 0 - 8	2.82 1.18 0 - 4	39.80 15.82 23.85 - 85.68
3	Adaptive Feedback; Increasing Ratio Review	M: 1.29 SD: 1.31 Range: 0 - 4	1.06 1.34 0 - 5	42.89 17.24 15.46 - 79.54
4	Adaptive Feedback; Immediate Review Only	M: 2.35 SD: 2.15 Range: 0 - 8	3.00 1.70 1 - 8	34.65 15.23 12.97 - 77.07
5	Adaptive Feedback; No Review	M: 2.24 SD: 2.11 Range: 0 - 8	3.35 2.06 0 - 7	32.10 13.29 10.77 - 61.84
6	Fixed Feedback; Increasing Ratio Review	M: 1.47 SD: 1.70 Range: 0 - 5	0.88 1.05 0 - 4	33.27 11.74 17.79 - 66.16

Note. Seventeen students in each group. Maximum score is 20.

After analyses of these planned comparisons, an F test was performed for all remaining independent comparisons (following Hays, 1973, pp. 600-607). Test statistics were: $F(2,96) = 3.63$, $p < .05$ for DEs and $F(2,96) = 16.77$, $p < .001$ for OLEs. There were no significant differences for instructional time, $p > .05$. Post-hoc analyses of all pairwise comparisons for DEs and OLEs were performed using the Newman-Keuls procedure. Though several comparisons were significant, those corresponding to research questions 4 and 5 were not significant.

An analysis of frequency and type of errors during instruction showed that there were no significant differences in these measures among groups. Nearly 42% of the errors during instruction were DEs. Analysis of covariance (with the student's pretest and vocabulary test scores as covariates) showed results identical to the above for all comparisons.

Discussion

These results suggest that for computerized drills:

1. Increasing ratio review techniques (e.g., 1-, 3-, 5-later review) are more effective than traditional review techniques (e.g., 1-later review) or no review at all. Moreover, 1-later review is no more effective than no review. This suggests that a 2-, 3-, 5- or a 2-, 4-, 6- later review schedule may have been more effective than a 1-, 3-, 5-later review schedule.
2. Although adaptive feedback without discrimination training was no more effective than fixed feedback in reducing the number of discrimination errors on the posttest, adaptive feedback with discrimination training significantly reduced the number of discrimination errors on the posttest. Thus, the effectiveness of adaptive feedback may be significantly lessened unless it is accompanied by discrimination training. For example, suppose a student confused "aunt - obasan" with "mother - okaasan." The student typed "okaasan" for "aunt." If the student was in the "adaptive" feedback group, the student received the DE feedback message: "okaasan is mother; aunt is obasan." If the student was never required to discriminate between the stimuli "aunt" and "mother" when presented simultaneously, however, (i.e., if there was no discrimination training), the student may not have been reinforced for attending to the first part of the DE feedback message ("okaasan is mother"). Thus, the student's attention may have been "short-circuited" since the student had to remember only the second part of the DE feedback message ("aunt is obasan") to successfully translate a future review presentation of "aunt;" this short-circuited message was identical to the fixed feedback message.

Note that among the three increasing ratio review groups--two with adaptive feedback and one with fixed feedback--there were no significant differences in the mean number of OLEs on the

posttest. Of course this is what you would expect because adaptive feedback and fixed feedback treat OLEs in the same way.

Frequently in non-drill computer lessons the student is required to type a missed answer immediately following corrective feedback. This requirement may be less than useful in facilitating learning. We suspect that the student learns to type the correct answer without attending to the question paired with the answer.

3. Finally, the additional presentations inherent in employing increasing ratio review and discrimination training techniques did not significantly add to the instructional time. For example, the mean number of item presentations for Group 1 (increasing ratio review and adaptive feedback with discrimination training) was 288 items ($SD = 129$), whereas the mean number of item presentations for Group 5 (no review and adaptive feedback) was 158 items ($SD = 72$). Yet, there were no significant differences between these two groups in instructional time. Thus, Group 1 completed more items per minute during instruction than did Group 5. An explanation for this result may be found in the group means for "time on posttest." An analysis of covariance (with "time on the typing test" as the covariate) showed that Group 1 (increasing ratio review and adaptive feedback with discrimination training) completed the posttest significantly faster than any other group, suggesting that the students in Group 1 were more "confident" of their answers. This is an important finding. More educationally effective procedures can be implemented without spending additional time in instruction.

What conclusions can be made from these findings that would assist instructional designers in implementing more effective computerized drills? Most important, increasing ratio review techniques should be employed. Exactly what specific review schedules are most beneficial and under what instructional settings remains a question for future research. Second, if a drill list includes stimulus-response pairs that may be confused with other stimulus-response pairs in the list, the drill should include adaptive feedback procedures. Discrimination training should be provided after discrimination error feedback so that the student has an opportunity to "work out" the confusion.

Implications for Instruction

Traditionally, drills have been used principally for teaching paired associates or for other non-generalizable tasks--fixed lists of items in which the instructional task is to memorize a unique response for each stimulus presented in the drill. Such drills are efficient, but they have a crucial limitation: knowledge of one stimulus-response pair is not generalizable to others. In fact, interchanging the members of the stimulus-response pairs is usually regarded as the limit to which drill-centered instruction can be generalized. With CFP, however, the drill format can be used to teach generalizations. Instead of teaching a stipulated list of instances, the drill format employing the CFP can be used to teach students correctly to identify members of a set to which they have not previously been exposed--to sort on the basis of characteristics.

As an example, the University of Illinois PLATO reading comprehension curriculum (Siegel, 1979) employs such a drill format with CFP to teach generalizable concepts. One segment of the curriculum uses a drill format to teach the skill of identifying the part of a sentence that answers WH-questions. The student is presented with a sentence:

While the knitting machine was invented in England as early as 1589, it was not until 1793 that the cotton gin was invented in America.

Then the student may be asked to identify the part of the sentence that tells "where the cotton gin was invented" by pressing one key to underline phrases in the example sentence one at a time; another key to register his answer.

As in a regular drill, when the student makes a discrimination error, the CFP procedures are effected. If, for example, the student responds to a "where" question by underlining the part of the sentence that tells "when," the DE feedback is: "No. That part tells when the cotton gin was invented. Underline the part that tells where the cotton gin was invented." This discrimination problem-- confusing "when" and "where" questions--is practiced on succeeding tasks in the drill; that is, additional tasks are automatically inserted into the lesson which focus on the when/where confusion. If the student cannot answer the original question after being given DE feedback, the student is told the correct answer (OLE feedback)--graphically, rather than through prose, as shown in Figure 1.

Look:

While the knitting machine was invented
in England as early as 1589, it was not until 1793
that the cotton gin was invented where ?

While the knitting machine was invented
in England as early as 1589, it was not until 1793
that the cotton gin was invented in America.

Figure 1. Graphic OLE Feedback in reading comprehension lesson

Unlike a paired associate drill, however, the subsequent iterations of the item generated by the CFP in increasing ratio review are modified to reflect the range of the concept. In Figure 1, for example, there are four phrases that may change: (a) "in England" may be replaced by "in Great Britain," "in the British Isles," or "in Europe;" (b) "as early as 1589" may be replaced by "in the sixteenth century," "in the late 1500's" or "almost 400 years ago;" (c) "not until 1793" may be replaced by "after the Revolutionary War," "two hundred years later," or "shortly before 1800;" and (d) "in America" may be replaced by "in the United States," "in our country," or "on this side of the Atlantic." These semantically "equivalent" phrases, or "flip-book" parts, greatly increase the number of different items that the student encounters. Unlike static paired associate drills, the item being reviewed changes from presentation to presentation in a non-random way.

The lesson thus encourages students to focus on the sentence structure and semantic relationships rather than on a particular memorized phrase. A carefully controlled experimental evaluation of the PLATO reading comprehension curriculum indicated that students were taught the generalized skills of finding information and paraphrasing, and that these skills persisted at least two months after initial instruction (Alessi, Siegel, Silver, & Barnes, 1982).

In summary, the most important instructional implication of CFP is that it allows the use of a drill format to teach generalizable concepts. Typically in such a "drill" set:

1. A single concept is taught. (In this case, "Which part of a sentence answers WH-questions?")
2. The number of actual items in the queue is small--limited to the set of subconcepts that make up the concept being taught. (In this case, three to four flip-book items each for who-questions, where-questions, what-questions, etc.)
3. On review presentations, items are modified in non-random ways to demonstrate the range of the subconcept. (In this case, the original "when" answer is modified to "in the sixteenth century," "almost 400 years ago," etc., and its place within the sentence is varied.)

As drill paradigms are more widely viewed as potential instructional tools for the teaching of concepts and sophisticated cognitive networks, drill paradigms will become central to the design of instructional lessons, and not merely an appended technique that is used to "firm-up" what has already been taught.

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